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Identifying the Cognitive Demands on Experts' Decision Making in Liver Transplantation

Gala MOROZOVA^a, Amanda MARTINDALE^a, and Ian CURRIE^b
^a *Human Performance Science research group, The University of Edinburgh*
^b *Transplant Unit, Royal Infirmary of Edinburgh, NHS Lothian*

ABSTRACT

Introduction. Cognitive task analysis (CTA) has recently gained the attention of surgical educators and the present study is investigating the cognitive demands of the Liver Transplantation procedure. **Methods.** In-depth interviews, following the Applied Cognitive Task Analysis protocol with four consultant transplant surgeons. **Results.** Eleven elements that show evidence of significant cognitive demands were extracted across the dataset. **Conclusion.** This study begins to reveal the origin and contents of transplant surgeons' decision-making expertise. Applying CTA techniques to this domain is an essential step to modernisation of surgical training and possesses value for both decision-making researchers and medical practitioners.

KEYWORDS

Expertise; surgery; applied cognitive task analysis; expert performance.

INTRODUCTION

Surgery is an increasingly complex performance domain, where decision making skills are of paramount importance (Alderson, 2010; Cuschieri, Francis, Crosby, & Hanna, 2001; Yates & Tschirhart, 2006). Several studies have focused on expertise acquisition and examined surgical trainees to determine correlates of surgical performance (e.g., Francis, Hanna, Cresswell, Carter, & Cuschieri, 2001; Wanzel et al., 2003). The results showed that innate technical abilities (e.g. steady hand, visuo-spatial ability) may help young surgeons to obtain surgical skills more quickly; however, it is experience and competent judgment that makes a difference to surgical performance (Norman, Eva, Brooks, & Hamstra, 2006; Smink et al., 2012). Previous research has shown that senior surgeons rank decision making and cognitive abilities as the most important non-technical skills for a surgical trainee (Cuschieri et al., 2001; Jacklin, Sevdalis, Darzi, & Vincent, 2008). Despite its importance, decision making receives little attention in surgical training models (Flin et al., 2007; Jaffer, Bednarz, Challacombe, & Sriprasad, 2009). A large portion of surgical education is based on assisting and observing more experienced colleagues, however, as senior staff develop expertise, they automate their procedural knowledge, making it difficult to articulate the steps taken in their decision-making process (Jaffer et al., 2009; Smink et al., 2012).

Clark, Pugh, Yates, Inaba, Green and Sullivan (2012) compared 3 methods for capturing surgeons' descriptions of how to perform a complex task and found that when experts were asked to free-recall the procedure they unintentionally omitted almost 70% of the information that novices need to successfully perform a task. In their study, they found that interviews following Cognitive Task Analysis (CTA) methodology were able to capture more decision and action steps from expert surgeons than unaided free-recall methods. Their findings complement previous research, suggesting that most forms of CTA show substantial benefits with respect to the accuracy and completeness of data obtained (Clark et al., 2012; Smink et al., 2012; Tofel-Grehl & Feldon, 2013). Moreover, it has also been shown in the literature that performance improvements in training for a number of surgical procedures can be attributed to CTA-based instruction (Clark et al., 2012; Sullivan et al., 2008; Tofel-Grehl & Feldon, 2013; Wingfield, Kulendran, Chow, Nehme, & Purkayastha, 2015). Additionally, research suggests that CTA-based instruction can increase the learning curve and accelerate the acquisition of expertise among trainees (Clark et al., 2012). Understanding the cognitive demands underpinning surgical decision making is necessary to ensure that training can prepare young surgeons to meet the increasing demands of their profession with flexibility and innovation (Cristancho, Vanstone, Lingard, LeBel, & Ott, 2013; Flin et al., 2007). This study, therefore, adopts a CTA methodology to improve the understanding of decision making expertise in transplant surgery and answer the following research question – what are the cognitive demands on experts' decision making in liver transplantation?

METHODS

A qualitative approach was chosen to collect rich data and capture high quality descriptions of surgeons' expertise. The Applied Cognitive Task Analysis (ACTA; Militello, Hutton, Pliske, Knight, & Klein, 1997) technique was adopted to collect information about experts' decision making processes. This method was chosen over other CTA techniques for a number of reasons. First of all, it comprises a combination of different techniques that complement each other and elaborate on different aspects of expertise. Secondly, study by Militello and Hutton (1998) showed that it requires relatively little prior training for the researcher and detailed instructional materials are available. Furthermore, ACTA has been used in NDM research with experts from a variety of knowledge domains and indicated high levels of validity and reliability in terms of its ability to generate relative data across participants (McAndrew & Gore, 2013; Militello & Hutton, 1998).

Participants

Purposeful convenience sampling was used to recruit four expert transplant surgeons (1 female, 3 male) from the Edinburgh Royal Infirmary. The number of participants was chosen according to Militello and Hutton's (1998) suggestion that three to five subject matter experts usually exhaust the domain of analysis. Professional occupation, expertise level, and willingness to participate in a study served as selection criteria. Recognition by fellow colleagues and years of experience were used as indicators of the expertise level. These criteria were chosen in accordance with ACTA's methodological recommendation and were also in line with Hoffman's (1998) expertise model, suggesting that all consultants can be considered experts.

At the time of data collection participants held the position of Consultant Transplant Surgeon performing both retrieval and transplant surgeries for liver, kidneys and pancreas. All participants had worked in healthcare for a minimum of 16 years (mean = 27,5 years) and had acquired a minimum of 4 years (mean = 13,7) of experience within their current position.

Materials

ACTA instructional materials and Job Aids were used for this study (Militello et al., 1997). These in-depth interviews utilise a combination of knowledge elicitation techniques to uncover different elements of expertise, and consist of three stages: Task Diagram, Knowledge Audit and Simulation Interview.

The first stage of the interview, task diagram, prompts the surgeon to give a broad overview of the task and to indicate the difficult cognitive elements. The interview opened with the question: "Think about what you do when you perform a liver transplant surgery. Can you break this task down into between three and six steps?" (Militello et al., 1997). After the diagram is drawn, the experts were asked to identify areas of the task that demand complex cognitive skills. In this study 'Liver Transplantation' was chosen for analysis, as a cognitively challenging task in which all participants have expertise.

The 'Knowledge audit' builds upon the information received in the first stage and uncovers different elements of expertise using a set of 8 probes (Militello et al., 1997). This technique allows the researcher to elicit examples of cognitive skills, detailed information about the selected task, and to contrast expert and novice performance. Although, a simulation scenario was developed for this study due to time constraints and limited availability of experts it wasn't possible to conduct this stage with all participants and therefore it was omitted. A study by McAndrew and Gore (2013) examined financial traders' decision making using only Stage 1 and Stage 2 of the ACTA protocol and showed that it is sufficient to identify cognitive demands and compile practical recommendations.

RESULTS

To demonstrate the richness and complexity of qualitative data generated, a number of illustrative examples are presented to outline the results derived from Stages 1 and 2 of ACTA. Finally, extracts from an overall cognitive demands table are presented and discussed to summarise the findings of the study.

Stage 1: Task Diagram

The number of steps and level of detail varied among participants. The Combined Task Diagram (see Figure 1) is presented to summarise steps identified across the sample. This task diagram provides a broad overview of the intraoperative phase of liver transplant surgery and consists of five steps.

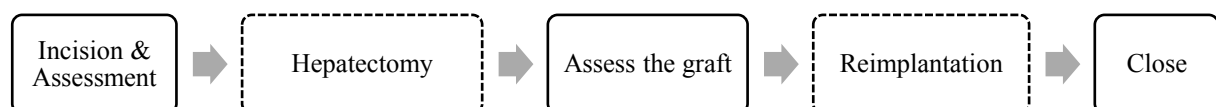


Figure 1. Combined task diagram

Participants, in one form or the other, said that all of its steps require a lot of cognitive skills. Although some of the participants identified more than two cognitively challenging elements, Hepatectomy and Reimplantation were highlighted as cognitively challenging by all participants.

Stage 2: Knowledge Audit

Table 1 provides an extract from Transplant Surgeon B's knowledge audit. This probe from the ACTA protocol elicits the overarching elements that form the 'big picture' for the liver transplantation task. Surgeons were asked to give an example and name major elements they have to know and keep track of. Four components were identified – estimated difficulty of operation, timing, patient characteristics, and quality of the graft. As Transplant Surgeon B explained, these are the elements that a surgeon needs to be aware of throughout the entire process, as they will affect all decisions that one makes. He noted that it is difficult for novices to understand the whole situation and maintain a big picture view. This is due to novices often focusing solely on the part that they are trying to learn at the moment, and not on the entire operation.

Table 1. Knowledge Audit Table Illustrative Example Transplant Surgeon B

Example	Cues & Strategies	Why Difficult?
<i>Big picture...</i> <ul style="list-style-type: none"> Difficulty of operation Timing Patient Quality of the organ 	Patient characteristics; Time available; Quality of the organ; Difficulty of the operation; Operating staff (seniority, number, fatigue) <ul style="list-style-type: none"> Depending on these factors decide how to approach the operation Accomplish hepatectomy safely (without too much blood loss; instability in the patient) Start implantation phase when the patient is stable Accomplish both in reasonable time (no excessive ischemia time, but not in a rushed manner) 	<ul style="list-style-type: none"> Focused on the part that they are trying to learn at the moment, not on entire operation Struggle to anticipate the difficulty as they haven't seen a lot of cases

Cognitive Demands

To integrate data drawn across the four task diagrams and knowledge audits from experts and summarise the results of the study a cognitive demands table (see Table 2) was compiled. Overall, eleven elements that show evidence of significant cognitive demands were extracted across the dataset: (1) Anticipate difficulty of the operation and choose how to approach it; (2) Assemble appropriate team & equipment; (3) Decide if portacaval shunt is feasible and necessary; (4) Complete hepatectomy in reasonable time; (5) Choose appropriate technique and pace for dissection; (6) Spot abnormalities in the liver graft; (7) Decide what to do if patient becomes unstable after perfusion; (8) Control bleeding; (9) Assess appearance of the liver; (10) Decide if blood supply for the graft is adequate; (11) Self-monitoring. There were no contradicting themes and examples across the sample. The cognitive demands which emerges had common elements and should not be considered on their own, but rather as a whole, to provide a complete picture of cognitive challenges in transplant surgery.

Cognitive Element	Why Difficult?	Common Errors	Cues & Strategies Used
(2) Assemble appropriate team & equipment	<ul style="list-style-type: none"> Don't know and therefore cannot assess the team Don't realise how difficult operation will be Want to acquire more experience, therefore are reluctant to delegate Not used to having 100% responsibility Don't want to get bad reputation by demanding more senior assistants (e.g. scrub nurses) 	<ul style="list-style-type: none"> Blaming yourself for what is a team failure Not realising when you need more senior/additional assistant Losing time and concentration waiting for additional equipment/ staff 	<ul style="list-style-type: none"> How sick is the patient? What complications to expect Who is available (fatigue) Equipment (do you need anything extra) Make sure everything is ready before the operation begins, that you have the right team, right equipment
(4) Complete hepatectomy in reasonable time	<ul style="list-style-type: none"> Difficult to judge the time during the operation Confidence, don't want to ask for help Might not have technical skills to complete hepatectomy safely and quickly Don't know surgeons responsible for retrieval 	<ul style="list-style-type: none"> Not realising how long the operation will take given the 'factors' Not asking for help Asking for help when a lot of time is consumed Wasting too much time and compromising graft's quality 	<ul style="list-style-type: none"> Familiarity of the surgeon responsible for the retrieval Condition of the patient and donor liver Anticipated difficulty of the hepatectomy Start the operation as early as possible to minimise ischemic time If confident in the retrieval surgeon and graft's quality, start before the liver has arrived in the building Ask for a senior/additional assistant, if you expect a difficult hepatectomy

Table 2. Extract from the Cognitive Demands Table

DISCUSSION

The results of this study make a unique contribution to the literature through investigation of the cognitive demands of liver transplantation and support previous research on decision-making expertise in surgery. The ability to anticipate operation's difficulty and foresee complications, which experts often referred to, as well as the majority of the cognitive demands identified, are closely related to the situation awareness concept proposed by Endsley (1997). Understanding the situation and being aware of patient and donor characteristics coupled with the proper assessment of one's team and one's own capabilities were found to be crucial for making effective decisions. This supports previous research suggesting that situation awareness is one of the driving factors in the decision making process in surgery and other performance domains (Cuschieri et al., 2001; Endsley, 1997; Flin et al., 2007; Yule, Flin, Paterson-Brown, & Maran, 2006). Strategies reported by experts in this study also fall into Cristancho and colleagues' (2013) model of surgical decision-making, however, more research is needed to fully test this model.

This study has several implications for educators and surgeons themselves. Educators could use these results to enrich existing training programmes with expertise-based knowledge. Causer, Barach and Williams (2014) reviewed how medical education can benefit from the systematic use of the expert performance approach as a framework for measuring and enhancing clinical practice, and came to a conclusion that in order to optimise the training of medical professionals, both instructional materials and training approaches have to be guided by empirical research from the learning and cognitive sciences. In terms of application of the results to surgical education and training, expert surgeons could use the Cognitive Demands Table and task diagrams to focus more on articulating their decision making while performing cognitively challenging steps of the operation for teaching purposes (e.g. cognitive apprenticeship). Furthermore, SMEs noted that the materials generated in this study would be particularly useful for newly appointed Consultant Surgeons, as they enter a role which puts the responsibility for the operation on their shoulders for the first time. The cognitive demands and strategies described in the Cognitive Demands Table could help maintain awareness of the key elements and big picture of the procedure. Future work could focus on translating these materials into a checklist for use immediately prior to the procedure, to ensure all necessary preparations are in place and serve as a reminder of the key elements to keep track of during the operation.

Limitations

This research has some important limitations that have to be taken into consideration. First of all, despite two decades of empirical enquiry NDM still requires further theoretical and methodological refining to achieve more advanced level in studies of expertise in real-life settings. It also needs to be noted that one interview structure does not always suit all participants. Although a great volume of relevant data was generated following the ACTA methodology, it was sometimes difficult for experts to recall a specific situation because, as surgeons mentioned, cases in which they managed to avoid complications using expertise didn't register in their memory.

Although it is worth noting, that the Simulation Interview method was omitted in this study, which could have addressed this issue. However, there are certain challenges associated with using the Simulation Interview part of ACTA. First of all, it takes a lot of time from both the research team and SMEs to create and pilot appropriate simulation materials and then to schedule and conduct additional 1,5 hours of interviews. Secondly, it is hard to estimate the amount of detail that needs to be included in the scenario to avoid purely hypothetical answers, as many decision and actions will depend on the context (e.g., resources available, team members experience, patient characteristics). Perhaps, complimenting Stages 1 and 2 of ACTA protocol with the analysis of documentation or observations would be a more feasible solution.

Another limitation of this study is generalizability, as it only includes four participants from a single institution. This is consistent with ACTA recommendations (Militello et al., 1997) and CTA literature in general (Schraagen, 2006; Smink et al., 2012; Sullivan et al., 2008; Tofel-Grehl & Feldon, 2013). Nonetheless, these surgeons all practice at the same hospital and local factors may generate similarity in opinion and techniques. This could explain why no contradicting descriptions of cognitive demands were found among participants. Expanding the sample to a national group of experts might yield more generalizable results. However, chosen methods are consistent with other published CTA studies and may, in fact, present greater value for implementation at the Edinburgh Royal Infirmary as its findings are generated from participants whose decision making is already framed by the organisational constraints of this hospital.

Future Research

Despite the limitations, this study creates opportunities for further research on expertise in general and in transplant surgery in particular. First of all, as this study was the first documenting cognitive demands on decision making during liver transplant surgery, the cognitive steps and demands identified must be examined in more detail, to ensure accuracy and completeness of these findings. Another important direction that future researchers and

educators should take is to analyse the current teaching programme and find opportunities to integrate experience-based knowledge and expert performance approach into surgical training.

Participants often mentioned the importance of situation awareness, along with teamwork factors, confidence, and coping skills, in overcoming cognitive challenges of their profession. These influence and implications should be investigated further in order to enhance surgeons' performance and nurture expertise among junior staff.

CONCLUSION

The main objective of the present study was to identify the cognitive demands on expert decision making in transplant surgery. Conducting a field study of expertise using a detailed cognitive task analysis, this research begins to reveal the origin and contents of transplant surgeons' decision-making expertise. Examples and findings presented here illustrate how experts use cues and strategies to overcome cognitive challenges during liver transplantation. Although these findings cannot be contrast with similar research, as there is no literature directly investigating cognitive demands in this discipline, results of this study relate to the previous research on decision making expertise in surgery and possess value for both decision making researchers and medical practitioners.

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Bi-annual International Conference on Naturalistic Decision Making

HISTORY OF NDM CONFERENCES

1989	Dayton	NDM1 set the stage for expanding the study of problem solving and decision making, linking it to expertise studies, making it more pertinent to the needs of the applied community, and giving greater focus on national needs. This Conference served as a "call."	Klein, G., Orasanu, J., Calderwood R., & Zsombok, C. E. (Eds.), (1993). <i>Decision making in action: Models and methods</i> . New York: Ablex Publishing.
1994	Dayton	NDM2 was more specific, dealing with a host of application areas and some tentative results from NDM work. Ideas for future directions were charted since NDM was still largely a promissory note.	Zsombok, C. E., & Klein, G. (Eds.), (1997). <i>Naturalistic Decision Making</i> . NJ: Lawrence Erlbaum.
1996	Aberdeen, Scotland	NDM3 highlighted the interest in NDM on the part of European researchers, and served to integrate the ideas of NDM with the existing paradigms in the European community, such as Work Analysis.	Flin, R., & Salas, E. (Eds.). (1998). <i>Decision making under stress: Emerging themes and applications</i> . London: Ashgate
1998	Washington DC	NDM4 represented some of the pay-off from the initial promissory notes. A host of research studies was presented on diverse topics. There was a healthy debate on the relation of NDM to other paradigms, including those of human factors and "cognition in the wild."	Salas, E., & Klein, G. (2001). <i>Linking expertise and naturalistic decision making</i> . Mahwah, NJ: Lawrence Erlbaum Associates.
2000	Stockholm, Sweden	NDM5 was organized around a matrix combining methodology (Cognitive Task Analysis, Observational Methods, Microworld Techniques) and application areas (Distributed Decision Making, Decision Errors, Learning From Experience, Motivation and Emotion, and Situation Awareness and Training).	B. Brehmer, R. Lipshitz, & H. Montgomery (Eds.). (2004). <i>How professionals make decisions</i> . Mahwah, NJ: Lawrence Erlbaum Associates.
2003	Pensacola Beach, FL	NDM6 addressed the issues that experts face in situations that fall outside 'the routine'. Other discussions included NDM and cognitive task analysis methodology, NDM and traditional lab-based DM, and microcognition to macrocognition.	Hoffman, R. R. (Ed.) (2006). <i>Expertise out of context: Proceedings of the Sixth International Conference on Naturalistic Decision Making</i> . Mahwah, NJ: Erlbaum.
2005	Amsterdam, The Netherlands	NDM7 emphasized five themes: adaptive decision support, cognitive ethnography, crime and decision making, crisis management, and medical decision making. In sessions, the NDM framework was applied to new and diverse domains, such as landmine detection, judgments in crime situations, and space exploration.	Schraagen, J.M., Militello, L., Ormerod, T. & R. Lipshitz (Eds.). (2008). <i>Naturalistic Decision Making and Macrocognition</i> . London: Ashgate.
2007	Monterey, California	NDM8 represented the diversity of research within NDM including: knowledge management, applications to organisations and teams and military security operations. Debate centred upon the appropriateness of the macro-cognition construct and the methodological challenges that continue to face the field.	Mosier, K. L. & Fischer, U. M. (Eds.) (2010). <i>Informed by Knowledge: Expert Performance in Complex Situations</i> . Sussex, UK: Taylor & Francis.
2009	London, UK	NDM9 addressed the effect of modern computing technology on decision making that occurs in naturalistic settings such as medical diagnosis and treatment, command and control, financial markets, information analysis, team decision making and coordination.	Wong, B. L. W. and Stanton, N. A. (Eds.) (2009) <i>Naturalistic Decision Making and Computers: Proceedings of the 9th Bi-annual International Conference on Naturalistic Decision Making</i> , British Computer Society, London Stanton, N.A., Wong, W., Gore, J., Sevdis, N. & Strub, M. (2011) Critical Thinking. <i>Theoretical issues in Ergonomics Science</i> . 12 (3): 204-209
2011	Orlando, Florida	NDM10 brought together researchers and practitioners from diverse domains who seek to understand and improve how people actually perform cognitively complex functions in demanding situations.	Fiore, S. M. & Harper-Sciarini, M. (2011). <i>Proceedings of the 10th Bi-Annual International Conference on Naturalistic Decision Making</i> . University of Central Florida. ISBN 978-1-4507-7872-5 Harper, M. & Sciarini, L. (2011) Selected Papers from the 10th Bi-Annual International Conference on Naturalistic Decision Making. <i>The International Journal Cognitive Technology</i> 16: 2, 1-63
2013	Marseilles, France	NDM11 focussed on sensemaking, trust and uncertainty management and expertise interacting with technical systems across a wide range of operational domains.	Chaudet, H., Pellegrin, L., Bonnardel (2015) Special issue on the 11th conference on Naturalistic Decision Making, <i>Cognition, Technology & Work</i> Volume 17: 3, 315-318
2015	Washington DC	NDM12 extended NDM thinking reaching across domains, disciplines and applications. Since the first 1989 NDM conference the NDM community of practice has grown worldwide extending well beyond the early fire ground commander studies hence an integration of multidisciplinary efforts to improve work in complex domains	Mosier, K. & Militello, L. (2016) Extending Naturalistic Decision Making: Reaching across domains, disciplines, and applications. <i>Journal of Cognitive Engineering and Decision</i> . 10, (3), 227-228

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